The Economic Value of Life: Linking Theory to Practice

J. STEVEN LANDEFELD, PhD, AND EUGENE P. SESKIN, PhD

Abstract: Human capital estimates of the economic value of life have been routinely used in the past to perform cost-benefit analyses of health programs. Recently, however, serious questions have been raised concerning the conceptual basis for valuing human life by applying these estimates. Most economists writing on these issues tend to agree that a more conceptually correct method to value risks to human life in costbenefit analyses would be based on individuals' "willingness to pay" for small changes in their probability of survival. Attempts to implement the willingness-topay approach using survey responses or revealedpreference estimates have produced a confusing array of values fraught with statistical problems and measurement difficulties. As a result, economists have searched for a link between willingness to pay and standard human capital estimates and have found that for most individuals a lower bound for valuing risks to life can be based on their willingness to pay to avoid the expected economic losses associated with death. However, while these studies provide support for using individual's private valuation of forgone income in valuing risks to life, it is also clear that standard human capital estimates cannot be used for this purpose without reformulation. After reviewing the major approaches to valuing risks to life, this paper concludes that estimates based on the human capital approach—reformulated using a willingness-to-pay criterion—produce the only clear, consistent, and objective values for use in cost-benefit analyses of policies affecting risks to life. The paper presents the first empirical estimates of such adjusted willingness-topay/human capital values. (Am J Public Health 1982; 72:555–566.)

Introduction

Among the most hotly debated areas of public policy are those involving risks to human health and safety. For example, in the occupational area, industry representatives claim that exposure standards are so stringent they would fail any reasonable cost-benefit analysis. At the same time, public interest groups claim that cost-benefit analysis is a biased tool used to further the ends of industry to the detriment of workers' health and safety.

Central to this debate is the valuation of human life. Although some claim the value of human life cannot be expressed in monetary terms, the competing demands on scarce public funds require that some value be placed on programs that save lives. Refusal to place an explicit value on life merely forces implicit valuations that are made as part of decisions to fund or not to fund public projects as well as decisions to take other regulatory actions.

Most economists writing on these issues agree that the conceptually correct method to value risks to human life in cost-benefit analyses should be based on individuals' willingness to pay (or on individuals' willingness to accept compen-

sation) for small changes in their probability of survival.* Despite this agreement, however, controversy continues on the appropriate technique for actually producing estimates for valuing risks to life. This paper reviews the major issues in this area and concludes that estimates based on the human capital approach—reformulated, using a willingness-to-pay criterion—produce the only clear, consistent, and objective values for use in cost-benefit analyses of policies affecting risks to life.

Methods Used to Value Life

Human Capital (HK)

The human capital (HK) approach to valuing life has a long history dating back to the works of Petty² and Farr.³ Later studies by Fein,⁴ Mushkin and Collings,⁵ Weisbrod,⁶ and Klarman⁷ polished and improved the theoretical and practical underpinnings of the approach. Finally, Rice⁸ in her pathbreaking article, "Estimating the Costs of Illness," effectively codified the empirical application of the technique.

AJPH June 1982, Vol. 72, No. 6

Address reprint requests to J. Steven Landefeld, PhD, BE-52, Bureau of Economic Analysis, US Department of Commerce, Washington, DC 20230. Dr. Seskin is also with that agency. This paper, submitted to the Journal September 24, 1981, was revised and accepted for publication January 22, 1982.

Editor's Note: See also related editorial p 536 this issue.

^{*}It should be recognized that the amount people are willing to pay depends, in part, on their ability to pay. Hence, any estimate of willingness to pay is dependent upon a given distribution of income. Similarly, because of these wealth effects, the amount people are willing to pay may differ from the amount they would be willing to accept as compensation.

In the standard HK approach, it is assumed that the value to society of an individual's life is measured by future production potential, usually calculated as the present discounted value of expected labor earnings.** Some analysts, like Weisbrod, have employed expected earnings net of consumption, based on the notion that when an individual dies not only is productive contribution lost, but also claims on future consumption.¹² Therefore, as would be the case for physical capital, the net loss to society is the difference between earnings and maintenance (consumption) expenditures. Whether the gross HK approach or the net approach—adjusting for consumption—is employed, each is implicitly based upon the maximization of society's present and future production.***

Since standard HK estimates are constructed from society's perspective, labor earnings are evaluated before taxes as representing the actual component of GNP, rather than after-tax earnings which represent the relevant magnitude to the individual. In addition, non-labor income is excluded since individual capital holdings (and associated earnings) are not materially affected by an individual's continued existence. Thus, standard HK estimates incorporate a zero value for persons without labor income such as retired individuals with only investment or pension income.

By its emphasis on economic product, the HK approach also ignores other dimensions of illness and death as well as nonmarket activities that may be more important to an individual than economic loss. These include pain and suffering, aversion to risk, and loss of leisure which, itself, has value for the individual and perhaps for others as well. Furthermore, the only adjustment for nonmarket activities in HK estimates is the imputation of a value for housekeeping activities. These calculations are usually based on available information from time-use studies combined with data on wages of market substitutes for the relevant household activities.

An important issue that must be resolved to implement the HK approach involves the choice of an appropriate "social" discount rate to convert future earnings into present values. The problem amounts to determining what

TABLE 1—Present Value of Future Earnings of Males by Selected Age Groups, 1977^a (1977 dollars)

Age Group (years)			
	2.5 Per Cent	6 Per Cent	10 Per Cent
1 to 4	405,802	109,364	31,918
20 to 24	515,741	285,165	170,707
40 to 44	333,533	242,600	180.352
65 to 69	25,331	21,801	18.825

^aDollar figures based on the present value of both expected lifetime earnings and housekeeping services at 1977 price levels and an annual increase in labor productivity of 1 per cent.

Source: Dolan, Hodgson, and Wun. 14

society forgoes when it invests in life-saving programs. The choice is made difficult because of the effects of taxes and risk aversion which cause the rate of return to society's investments to diverge from the rates of return to private investments. For example, taxation means that the before-tax rate of return to private investment (the marginal productivity of capital) will exceed the after-tax rate of return to the individual investor (the individual's rate of time preference).‡ Risk aversion works in the same direction, resulting in a risk premium that causes a divergence between the marginal productivity of capital and the individual's rate of time preference.

Although the problem of choosing a discount rate arises in the evaluation of investments in most public programs, the long life of "investments" in HK—with life expectancies on the order of 70 years—greatly magnifies the difficulty. For example, Table 1 shows a range of HK values when different real discount rates are used to estimate the present value of forgone earnings of males by selected age groups.‡‡ As can be seen, the values are significantly larger for low discount rates than for high ones, especially in the case of children whose stream of earnings will be the longest. At a real rate of 10 per cent—the rate of discount recommended by the Office of Management and Budget (OMB)‡‡‡—the value for males aged 1 to 4 is less than one-tenth the value corresponding to a real rate of 2.5 per cent. At the same time, choice of a discount rate can affect the relative valuations placed on persons in specific age groups. For example, according to the Table, at a real rate of 6 per cent, males aged 20 to 24 are valued higher than males aged 40 to 44; whereas, at a real rate of 10 per cent, the reverse is true. The usual response to

^{**}Rice8 and Cooper and Rice9 estimated the cost of illness in the United States by using the HK approach to calculate *indirect* costs in the form of forgone earnings due to sickness and death and then adding the *direct* costs based on medical expenditures for prevention, diagnosis, and treatment. Subsequently, Hartunian, Smart, and Thompson¹0 suggested that in assessing prevention programs, incidence-based estimates of the costs of illness should replace the prevalence-based estimates used by Rice. More recently, it has been suggested that especially for fatal illnesses, an adjustment should be made to account for the fact that while those who die may suffer substantial costs before their deaths, society also avoids significant health-related expenses because of their deaths; on this point, see National Academy of Sciences.¹¹

^{***}It should be noted, however, that if society merely wanted to maximize the gross national product (GNP)—a common measure of welfare—a less expensive course of action than investments in life saving might be to eliminate immigration barriers or discourage birth control. Furthermore, health measures that reduce death rates and add to GNP by increasing the labor force, could actually lower per capita GNP, if the number of workers increases relative to the amount of output they produce (see Mushkin and Landefeld¹³).

[‡]A standard result of capital theory is that, given perfect capital markets, rational individuals will adjust their savings and consumption patterns so that their private rate of time preference will equal their private rate of return on investments.

^{‡‡}Since estimates of future earnings are generally made in constant or base-year dollars, whatever nominal discount rate is chosen must be converted to a real rate by an adjustment for inflation.

^{‡‡‡}According to OMB, "the prescribed rate of 10 per cent represents an estimate of the average rate of return on private investment before taxes and after inflation." 15

these types of occurrences is for researchers (see, for example, Berk, et al¹⁶) to present sensitivity analyses using several discount rates. However, while this is notable on paper, public officials often complain, with some justification, that this practice is not only confusing, but it can also lead to abuses in which persons choose a rate that is most favorable to the outcome they desire.

Despite the conceptual problems associated with the HK approach, the technique is widely used.* To some extent this is an artifact of the relative ease in computation since necessary data are not difficult to obtain. More to the point, the standard HK approach has the virtue of providing numerical estimates that are indisputable measures of what they say they are: objective numbers based on life expectancy, labor force participation, and projected earnings.

Willingness to Pay (WTP)

Because of the inadequacies associated with the HK approach, economists have searched for alternatives. Mishan, in one of the early theoretical discussions on valuing human life, suggested that the only logically consistent basis for the valuation of loss of life in safety decisions should be the same criterion used by welfare economists in other areas of cost-benefit analysis, namely, the "potential Pareto improvement principle." ¹⁸

A "potential Pareto improvement" is said to exist when individuals who gain from a social change are able to compensate those who stand to lose from the change and still leave a net gain. Thus, Mishan concluded that the relevant question is, What are individuals "willing to pay" (or accept as compensation) for a change that will affect loss of life? He went on to note that in most public safety decisions, the issue is not the value of an *identified* individual's life; rather, it is the value of a reduction in the probability of death for a given population. In other words, it is the aggregate value a population at risk places on programs that save "statistical" lives or the sum of the amounts individuals are willing to pay *ex-ante* to "buy" small reductions in the probability of their death.**

An example may help to illustrate this point. Suppose each person in a population of 100,000 is willing to pay \$25 for a program that is expected to reduce the overall probability of death from 0.0009 to 0.0008. Since this is equivalent to a reduction in the death rate from 90 per 100,000 to 80 per 100,000, the implied value per each of the 10 "statistical" lives saved is \$250,000.

In theory, WTP represents a comprehensive measure of the private valuation individuals place on small reductions in the risk (probability) of death.*** Conceptually, everything that contributes to an individual's well-being would be captured in the measure, including non-labor income, the value of leisure, aversion to risk, and the value of avoiding pain and suffering. In addition, the WTP would incorporate an implicit rate of time preference reflecting the weight given to future benefits of living.

A number of researchers have acted upon Mishan's counsel and attempted to calculate WTP estimates of the value of a statistical life. These attempts have proceeded along two general directions: 1) analyses of direct survey responses by individuals, and 2) statistical estimation of individuals' revealed preferences. Each approach has problems associated with it.

Acton, ¹⁹ Jones-Lee, ²⁰ and Landefeld²¹ have carried out survey estimates of individuals' WTP for reductions in risk of death (see Table 2). Acton, for example, asked individuals open-ended questions about their WTP for a coronary care unit that would reduce risk of death from heart attack by 0.002. He found that the average person in his sample was willing to pay approximately \$76 for the unit. Stated differently, the aggregate WTP, in a community of N such individuals, would be \$76N/0.002N = \$38,000 per statistical life saved.‡ Jones-Lee, ²⁰ in a survey concerning safety and airline travel, employed similar methods and found a value per statistical life of \$8.4 million. Landefeld, ²¹ in another survey on the WTP for reducing cancer mortality, calculated a value of \$1.2 million per statistical life saved.

Although the survey method is an improvement over the HK approach in that it is based on WTP, there remain serious problems in its application. For example, what individuals say they will do may vary considerably from what they will actually do when confronted with a true market test, often because of a lack of information. Furthermore, strategic behavior may occur: If, on the one hand, respondents believe that they will be assessed amounts equal to their WTP, they may deliberately understate their WTP, especially if provision of a "public good" is in question such as a program that decreases cancer incidence for all. If, on the other hand, respondents do not believe that they will be assessed according to their WTP, they may overstate their WTP in an attempt to promote the provision of a public good.‡‡ Finally, social psychologists, reviewing these survey attempts to value life, have raised questions about the ability of individuals to respond rationally and consistently to the abstract and complex questions involving hypothetical risk.31,32 For example, an increase of 0.00002 in workers' risk of death would represent an increase in the overall work fatality rate of approximately 25 per cent. Yet, one would expect quite different WTP responses depending on which of these two ways were used to characterize this change in risk in a survey questionnaire.

The studies undertaken to determine WTP on the basis of revealed preferences have been based on observations of compensation necessary to induce individuals to voluntarily

^{*}A recent survey of the literature by the Public Services Laboratory¹⁷ turned up well over 230 separate cost-effectiveness/cost-benefit analyses of illness, many of which used the standard HK approach.

^{**}See Mishan,18 pp 159-163.

^{***}Note, that people are not asked to place a value on saving (with probability one) their own, relatives', or any other identified lives. For many, the only limit to these latter valuations would be one's ability to pay.

[‡]As noted in Table 2, all figures are in 1977 dollars.

^{‡‡}This difficulty in ascertaining the true WTP for publicly-provided programs is known as the "free-rider problem."

TABLE 2—Willingness-to-Pay Estimates of the Value of Life^a

Method	Value per Statistical Life (thousands of 1977 dollars) ^b	
Survey Approach		
Acton ¹⁹	38	
Jones-Lee ²⁰	8,440	
Landefeld ²¹	1,200	
Revealed Preference		
Labor Market		
Dillingham ²²	277	
Thaler and Rosen ²³	364	
Viscusi ²⁴	1,650	
Smith ²⁵	2,045	
Olson ²⁶	5,935	
Consumption Activity		
Dardis ²⁷	101°	
Ghosh, Lees, and Seal ²⁸	260	
Blomquist ²⁹	342	
Portney ³⁰	355	

*Where a study included a "central" or "most reasonable" estimate, that is shown; where only a range was given, the lowest value is presented.

^bValues were converted to 1977 dollars using the US Bureau of Labor Statistics Consumer Price Index (CPI).

°It is unclear from the Dardis study²⁷ what year dollars apply, although the estimate presented here appears to be based on an average value for the period 1974–1979.

assume risk. Two categories of such studies are discussed below, one based on compensating differentials in the labor market, the other based on compensating differentials pertaining to consumption activities of more general populations.

As can be seen from Table 2, the labor market studies that have examined the extra compensation necessary to induce workers to take risky jobs—Dillingham,²² Thaler and Rosen,²³ Viscusi,²⁴ Smith,²⁵ and Olson²⁶—have yielded dollar estimates for the value of a statistical life ranging from \$277,000 to more than \$5.9 million. One explanation for this wide range is that important characteristics of the worker remain unmeasured in the statistical analyses. This can bias the resulting estimates and cause instabilities in the calculated values for a statistical life. However, even when Brown³³ used a data set that included a number of worker characteristics omitted from, or poorly measured in, other studies (for example, educational attainment, marital status, and health problems), he was unable to narrow the range in the estimated values of life.‡‡‡

The large range in the estimates of the value per statistical life from the labor market studies can be attributed to at least five general problems:

• First, wage premiums may not accurately reflect worker risk preferences if workers have incomplete information regarding the risks to which they are exposed. For

example, young and inexperienced workers (who actually have the highest accident rates) will underestimate the risks to which they are exposed if they use information on risks to all workers.

- Second, wage premiums may not be accurate measures of worker preferences if there are significant imperfections in the labor markets. This may be the case if new, inexperienced workers have relatively little bargaining power to demand appropriate premiums for risk.
- A third but related problem is sample self-selection. That is, either because of low incomes, lack of economic opportunities, or specific individual preferences, those who work in risky jobs will exhibit less risk aversion than the population as a whole.* Thus, WTP valuations based on risk premiums paid to such persons will understate the correct values applicable to the general population.
- Fourth, statistical problems arise in attempting to separate risk of death from risk of injury since compensating wage differentials will be accounting for both types of risks in most hazardous jobs. Smith,²⁵ for example, was unable to separate statistically the independent effects of risk associated with worker injuries from risk associated with worker fatalities.** Thus, the estimated wage premium associated with increased risk of death in certain jobs may have included a premium associated with increased risk of injury.
- Finally, data constraints may bias the statistical estimates. For example, estimates generated in the Viscusi,24 Smith,25 and Olson26 studies are biased upward because aggregate industry data were used instead of individual (micro) data. Consider Viscusi's procedure. He assigned a risk premium based on industry data to blue-collar workers in his sample who perceived themselves to be in relatively risky jobs. Those workers who did not perceive their jobs as risky were assigned a zero risk premium. Yet, one would expect individual risk premiums for all blue-collar workers to be significantly higher than industry risk premiums since the latter are based on data that include office workers and others in less risky environments. Hence, by using the lower industry values instead of the actual compensation necessary to attract workers to the more risky jobs, Viscusi may have overestimated the implied value per statistical life.***

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^{‡‡‡}As noted in Table 2, where the study included a "central" or "most reasonable" estimate, this is shown; where only a range was given, the lowest value is presented. In many cases the range of estimates was quite large and the size and significance of the risk coefficients (from which the estimates are derived) were extremely sensitive to the other variables included in the estimating equation and to the particular functional form used.

^{*}Some may even be risk takers in that they will accept a wage premium that is less than the amount necessary to compensate them for the expected value of their loss associated with the increased risk

^{**}When Smith included a control variable for injury rates, its estimated coefficient was not statistically significant. He attributed this finding to the fact that expected uncompensated losses from injuries are very small compared to those associated with death. However, given the higher likelihood of injury than death and the incomplete coverage of workers under compensation laws, it is more likely that the lack of significance was an artifact of multicollinearity problems associated with the correlation between fatality rates and injury rates.

^{***}Suppose Viscusi's sample consisted of workers in an industry, 9/10 of whom were in zero-risk jobs, 1/10 of whom were in jobs associated with an increased risk of death of 0.001. Use of the corresponding industry risk factor of 0.0001 ((9/10 \times 0) + (1/10 \times 0.001)) will substantially overstate the compensation per unit of risk; each statistical life will be valued at \$1,650,000 (\$165/0.0001) when the actual value should be \$165,000 (\$165/0.001).

In order to circumvent some of the problems noted above, especially the issue of sample self-selection, researchers have employed more general populations in estimating compensating differentials associated with various consumptions activities: Dardis27 examined purchases of smoke detectors; Ghosh, Lees, and Seal²⁸ analyzed time, fuel, and risk tradeoffs in highway driving; Blomquist²⁹ investigated seat belt use; and Portney³⁰ examined housing values and environmental risk. Although the estimates from the consumption activity studies span a narrower range than those from the labor market studies (see Table 2), many of the same data and statistical problems remain. For example, quantitative information on the risk-reducing potential of the various activities is scarce. Thus, in a study such as the one by Dardis,²⁷ risk estimates associated with the use of smoke detectors were based only on a personal communication with an employee of the National Bureau of Standards. The statistical difficulty of separating risk premiums from other confounding factors is also severe in these studies. For example, in estimating the risk premium associated with air pollution exposure, Portney³⁰ attributed the entire premium paid for improved air quality to reduced risk of death. However, as Portney recognized,‡ this overstates the "true" risk premium associated with death since "clean air also means lower cleaning, painting, and repair bills as well as enhanced aesthetic appeal."

Thus, in view of the large range of values associated with the survey results and despite some promising findings from the revealed-preference studies based on compensating differentials, practical application of these approaches is difficult.‡‡ As a consequence, some economists have attempted to redirect research in this area by addressing the question of whether there is a theoretical relationship between individual WTP (or individual willingness to accept compensation) for small changes in risk and the value of forgone future income as derived in applications of the HK approach.

Linking Willingness to Pay and Human Capital Valuation

The focus of the research linking WTP and HK valuation has been generally restricted to individual's WTP for the economic consequences associated with small changes in risk of death. The resulting WTP values—unlike survey or revealed-preference WTP estimates—are not designed to be comprehensive (including such items as pain and suffering and the value of leisure). On the other hand, given the

difficulties surrounding the survey and revealed-preference approaches, as well as their inherent subjectivity, this more narrowly defined approach provides less ambiguous input for the decision maker faced with evaluating life-saving programs.

Economists such as Usher,35 Rappaport,36 Conley,37 and Bailey³⁸ have attempted to link WTP to HK by specifying a priori what rational individuals (given sufficient time and information) should be willing to pay to avoid the financial losses associated with small risks to life. The models used by these researchers all stress the individual's decision process in making risk-avoiding choices. For example, as with WTP, it is assumed that an individual would weigh the economic risks and benefits relevant to, say, the purchase of a smoke detector or the use of a seat belt. In addition, the models incorporate certain restrictive assumptions about the hypothetical individuals: 1) their objective functions are based solely on the maximization of the expected value of discounted lifetime income; and 2) they are risk-averse and treat the economic losses associated with risks to life symmetrically with risks to financial and other assets. The results of these models demonstrate that for such individuals, the lower bound or minimum value per statistical life is equivalent to the expected value of discounted future income. While elegant expositions of this finding are available in the papers referenced above, the basic notion can be illustrated by a simple example.

Suppose there is a town with a population of 100,000 in which all persons have identical income and life expectancies as well as identical aversions to risk and rates of time preference. Furthermore, consistent with the models above, all individuals have as their objective function the maximization of the expected value of discounted lifetime income. Initially, risk of death and lifetime income are such that residents can expect with probability 1, a present value of lifetime income equal to \$400,000. Now suppose that residents are exposed to a risk that will cause a one time increase of 10 deaths so that they can expect only a probability of 0.9999 of surviving to enjoy their lifetime income. What should the individuals be willing to pay to avoid the economic losses associated with this increased risk?

As a result of the increased risk, the expected value of discounted lifetime income would be only \$399,960 (0.9999 \times \$400,000). As a consequence, each individual would experience a loss of \$40 in the expected value of discounted lifetime income. Therefore, as risk-averse individuals, they should be willing to pay at least \$40 to avoid a 0.0001 risk of a \$400,000 loss. The total WTP of residents would be at leat \$4 million (\$40 \times 100,000 residents), which is precisely equal to the present discounted value of lifetime income for 10 individuals, or \$400,000 per "statistical" life. Thus, under the assumptions noted above, it can be seen that the welfare-based aggregate value a population would be willing to pay ex ante to save "statistical" lives is equal to a HK-based estimate of the lifetime incomes of those lives.

The attempts to specify a priori the relationship between WTP and HK have not been without criticism. Cook³⁹ has charged that the underlying proofs lack generality be-

[‡]See p 77.30

^{‡‡}Recently, Blomquist³⁴ has defended the large variance in WTP estimates by noting that a pattern exists in which life values based on WTP decrease as the magnitude of the risk increases. In fact, he even suggests that this inverse ordering be used in public policy analysis. However, this ordering may be merely an artifact of the inability of individuals to perceive extremely low risks of death (or differences between low risks of death). That is, even if individuals are willing to pay more for larger risk reductions, they may be unwilling to pay proportionately more because they may be unable to distinguish between very small changes in risk of death. Hence, if life values were derived by dividing observations on relatively constant WTP by increasing levels of (relatively small) risk reductions, this pattern would always emerge.

TABLE 3—Simplified Expressions of the Alternative Methods for Valuing Lives

Method	Expression	Comments	
1) Human Capital	$\sum_{t}^{T} \frac{L_{t}}{(1+i)^{t}}$	T = remaining lifetime L _t = labor income ^a i = social discount rate; opportunity cost of society investing in life-saving programs	
2) Revealed-Preference Willingness to Pay	$\left[\begin{array}{cc} \sum_{t}^{T} & B_{t} \\ \frac{1}{(1+\rho)^{t}} \end{array}\right] \alpha$	$\begin{array}{ll} T & = \text{remaining lifetime} \\ B_t & = \text{benefits of living} \\ & = L_t + \text{NL}_t + \text{NM}_t + \text{P}_t \\ & \text{where } L_t & = \text{labor income}^a \\ & \text{NL}_t & = \text{non-labor income} \\ & \text{NM}_t & = \text{nonmarket activities and leisure} \\ & P_t & = \text{premium for pain and suffering} \\ \rho & = \text{individual rate of time preference} \\ \alpha & = \text{risk-aversion factor} \end{array}$	
3) Adjusted Willingness- to-Pay/Human Capital	$\left[\sum_{t}^{T} \frac{Y_{t}}{(1+r)^{t}}\right] \alpha$	$\begin{array}{ll} T & = \text{remaining lifetime} \\ Y_t & = \text{after-tax income} \\ & = L_t + NL_t \\ & \text{where } L_t & = \text{labor income}^a \\ & NL_t & = \text{non-linear income} \\ r & = \text{individual's opportunity cost of investing in risk-reducing activities} \\ \alpha & = \text{risk-aversion factor} \end{array}$	

^aMay include the imputed value of nonmarket time spent on housekeeping activities.

cause they rely on very specific forms of individual preference functions. For example, as Friedman and Savage⁴⁰ have shown, even individuals who are normally risk-averse may actually exhibit characteristics of risk takers when confronted by situations involving only very small expected losses (or gains). ### To counter this argument, it should be noted that when individuals are faced with small risks of large discrete losses—such as loss of home due to fire, major accidents, or costly illnesses—they often purchase insurance far exceeding the expected value of the loss. Thus, as Bailey³⁸ has demonstrated for purchasers of life insurance, such persons exhibit a WTP that greatly exceeds the discounted value of their future income. It might be expected, therefore, that persons confronted with life-threatening risks would also exhibit similar risk-averse behavior because even though the expected value of the loss is small, a large irreversible outcome is at stake.

Comparing the Alternatives

Table 3 presents simplified expressions that characterize what is captured in estimates based on the three approaches: 1) the "standard" HK forgone-earnings method; 2) the revealed-preference WTP method; and what will be referred to below as 3) the adjusted WTP/HK method. While the expressions appear somewhat similar in the sense that they each contain an argument representing a discounted stream of future "benefits," there are important differences that should be highlighted.

As noted earlier, standard HK estimates measure the value of life in terms of the forgone earnings or labor

contribution to GNP over a remaining lifetime (T).* In expression 1 of Table 3, this is represented by the summation over t of before-tax labor income (L_t). Non-labor income—such as that associated with rental payments from land or interest from capital holdings—is excluded since despite its contribution to GNP, it is not dependent upon an individual's continued existence. The discount rate (i) used to calculate the present value of forgone earnings represents the social opportunity cost of society investing in life-saving programs instead of some "next-best" alternative investments. While use of such a rate is conceptually appealing, in practice, it is difficult to ascertain the actual alternative investments society would forgo and therefore the relevant rate of return that should be applied.

The value of a statistical life under the revealed-preference WTP framework is derived from data on individuals' WTP for actions that result in small changes in their risk of death. To obtain a value per statistical life as presented in expression 2 of Table 3, these individual WTP estimates must be divided by the relative risk to the individuals. In expression 2 of Table 3 the future benefits (for which this WTP is revealed) are represented by the summation over t of B_t . In contrast to the HK estimates, these future benefits include more than labor income (L_t). They implicitly include non-labor income (NL_t), the value of nonmarket activities (NM_t) such as leisure, plus any premium individuals attach to the avoidance of pain and suffering (P_t). The discount rate (ρ) implicit in the individual's determination of the present

^{‡‡‡}Similarly, Cook⁴¹ observed—and Bailey⁴² concurred—that standard HK estimates will overstate WTP for persons who would commit suicide at very low incomes.

^{*}Human capital estimates that are adjusted for nonmarket activities such as housekeeping include increments that do not appear in GNP. However, for simplicity, such adjustments have been ignored in this discussion.

value of these future benefits is based on the individual's rate of time preference as opposed to the social opportunity cost (i) used for deriving the HK values. Finally, a risk-aversion factor (α) is shown to take account of the fact that individuals are likely to be at least as risk-averse with respect to loss of life in revealing WTP as they are with respect to financial loss.

The adjusted WTP/HK approach embodies characteristics of both the standard HK method and the revealedpreference WTP method. As with the standard HK approach, it includes only economic losses associated with death; hence, the resulting estimates can be considered a lower bound for the value per statistical life. As with the revealed-preference WTP method, it is based on WTP for small changes in risk of death from the perspective of the individual rather than from that of society. The value per statistical life using this method is represented in expression 3 of Table 3. In this case the future benefits are given by the summation over t of an individual's after-tax income (Y_t) . Y_t includes both labor income (L_t) and non-labor income (NL_t), but does not include measures of nonmarket activities or leisure. The discount rate (r) used to calculate the present value of future income represents the individual's (as opposed to society's) opportunity cost of investing in riskreducing activities using the household's assets.** Since, again, it is the individual's perspective that is important, the relevant rate of return is after taxes. A risk-aversion factor (α) is also applied for the same reason that it is thought to be relevant in the revealed-preference WTP estimates, namely, that persons should be at least as risk-averse with regard to loss of life as they are with regard to other assets in their investment portfolios.

The adjusted WTP/HK approach resolves some of the problems associated with the other two procedures. For example, because of the link with WTP, the adjusted estimates provide the welfare basis missing from the standard HK approach. At the same time, the choice of an appropriate discount rate to apply to future forgone income is made easier since the adjusted estimates are based on an individual rate of return rather than the more uncertain social rate of return. Finally, while the adjusted method does not include all the intangible factors that, in theory, would be included in revealed-preference WTP estimates (such as values for pain and suffering***) it does provide policymakers with a consistent, objective, and understandable procedure for placing an economic value on HK assets (lives) if one is willing to treat them symmetrically with financial assets. Furthermore, as discussed below, the requisite data are available to implement this procedure.

Adjusted Willingness-to-Pay/Human Capital Estimates

The literature referred to in the previous section exploring the relationship between WTP and HK valuation has been theoretical in nature, modeling the behavior of individuals making risk-avoiding decisions. Yet, no study has attempted to implement these models by producing adjusted HK estimates based on a WTP criterion. Below, such estimates are derived for males and females by 19 age groups. Before they are presented, however, it is important to discuss in some detail the three basic variables underlying the computations and the data used to measure them. The variables are: income, the discount rate, and the risk-aversion factor.

Income

The assumption behind the adjusted WTP/HK approach is that individuals maximize the expected value of their discounted future incomes. From the individual's point of view, the relevant income measure is total income after taxes.‡ Sources of total income include—in addition to labor earnings—such monetary items as interest, rents, royalties, private pensions, and transfer payments. Nonmonetary income is equally relevant. This encompasses nonmarket factors excluded from the GNP such as the value of homemaker services as well as specific imputations contained in the GNP.

Unfortunately, the only component of income that is readily available by age and sex groupings is labor earnings. Hence, several adjustments (and assumptions) must be made to obtain the desired income measure. Specifically, age-sex specific data on earnings from the US Bureau of the Census were adjusted by the ratio of disposable personal income to wages and salaries for the US population.‡‡ Disposable personal income was chosen for three reasons: 1) it is an after-tax measure of individuals' incomes; 2) it includes non-labor income as well as labor income; and 3) it incorporates imputations for in-kind income.‡‡‡

Discount Rate

To implement the WTP/HK method, one needs a private discount rate to calculate the present value of the

^{**}Jones-Lee²⁰ (p 14) noted that application of the potential Pareto improvement principle ''implies an unambiguous and straightforward resolution to the discounting question,'' namely, use of the individual's private rate of time preference. (As footnoted earlier in the Human Capital section, this rate would, in theory, equal the rate of return on household assets, that is, $r = \rho$.)

^{***}Linnerooth⁴³ and Blomquist⁴⁴ have observed that by ignoring such intangibles, standard HK estimates may significantly underestimate the "true" value of life.

[‡]Other researchers such as Conley³⁷ have focused on lifetime consumption rather than on income in order to exclude externalities such as those associated with bequests. Bailey,³⁸ instead, considered the household as a unit rather than the individual and assumed that household income was used to purchase lifetime consumption (including bequests). Since our paper focuses on an individual's total income, a dollar spent on an individual's own consumption is treated symmetrically with a dollar spent on other members of the household (including bequests).

^{‡‡}The implicit assumption here is that non-labor income is a constant proportion of labor income across all age and sex groups. However, as noted later, the aged are likely to receive a disproportionate share of their total income in this form. Therefore, while the inclusion of non-labor income raises the estimates for the aged, it is still likely to underestimate the "true" value.

^{‡‡‡}These include the rental value of owner-occupied housing, in-kind wages and salaries, food and fuel produced and consumed on farms, and the value of services furnished by financial intermediaries without payment.

TABLE 4—Insurance Risk Premiums

Туре	Risk Premiuma	
Private Health ^b		
Automobile ^c		
Physical damage (collision)	1.38	
Liability	1.45	
Life ^d	1.60	
Homeowner (multiple-peril) ^c	1.71	

The risk premium is defined as the ratio of insurance premium payments to insurance loss payments.

bSource: US Bureau of the Census48

°Source: Best⁴⁹ dSource: Bailey⁵⁰

stream of future income that would be forgone should the individual(s) in question die. In theory, this rate would represent the opportunity cost to the individual of investing in a risk-reducing activity or asset—such as installing a security system or buying a safer car—rather than making some alternative investment. A practical way to look at this issue is to ask the question, "What does the average individual earn on investments?" or, more to the point, "What is the average individual's after-tax rate of return on major economic assets?"

Published data on the rates of return to individuals on asset holdings are unavailable; hence, rate-of-return data for households were substituted. Specifically, rate-of-return series covering the period 1948 to 1978 were calculated for household investments in owner-occupied housing, consumer durables, time and savings accounts, bonds, corporate equity (or utility stocks), and non-corporate equity.* These series were then converted to after-tax rates by adjusting them for the relevant marginal federal, state, and local income tax rates.** Next, two weighted averages from the after-tax series were calculated—one for the top 1 per cent of wealth holders, the other for remaining households—to account for the fact that the wealthy own a disproportionate share of higher earning assets.*** Then, an "average" rate of return relevant to the population as a whole was derived by weighting these weighted averages. Finally, the resulting rate of return was made into a "real" rate by adjusting for inflation based on changes in the Consumer Price Index (CPI). The final figure representing the average after-tax real rate of return on households' major economic assets was found to be approximately 3 per cent over the period 1948 to 1978.

Risk-Aversion Factor

The final piece of information necessary to compute adjusted WTP/HK estimates involves the appropriate riskaversion factor to apply. As noted earlier, certain purchases of insurance provide strong evidence of risk aversion when households are confronted by small risks of potentially large losses. The profitable existence of insurance markets in some of these areas is dependent upon individuals being willing to pay amounts in excess of the expected values of potential losses. Thus, one can examine insurance risk premiums—the ratio of insurance premium payments to insurance loss payments—to gain a better understanding of household behavior toward risk aversion. Such premiums represent the relationship between WTP for reduced risk (the outlay for insurance) and the expected benefits of the insurance (the probability of a loss multiplied by the value of the asset in question).‡

Table 4 presents a number of insurance risk premiums derived from insurance statistics. As can be seen, they range from a value of 1.33 for private health insurance to 1.71 for multiple-peril homeowner insurance. Within this range, the most relevant risk premium to apply in valuing risks to life is that associated with life insurance, since in most cases it represents household WTP for potential losses associated with the death of an income-earning household member. Consequently, the adjusted WTP/HK estimates presented in the next section embody a risk-aversion factor of 1.60.

Empirical Estimates

Adjusted WTP/HK estimates are presented along with standard HK estimates in Table 5. As can be seen, there are substantial differences between the two sets of estimates. For example, for males aged 40 to 44, the adjusted WTP/HK estimate is almost four times as great as the standard HK estimate (\$660,193 compared to \$180,352). Before examining the implications of these differences, it is useful to analyze the sources of these differences in some detail.

The present value of estimated forgone earnings—the standard HK measure—of a male aged 40 to 44 is \$180,352 (discounted at 10 per cent). Adjustment of this figure for both non-labor income and the effects of taxes—using the ratio 1.33 of disposable income to wages and salaries—results in a present value of future after-tax income of \$234,422 (still discounted at 10 per cent).‡‡ Substitution of a discount rate based on a private real rate of return of 3 per cent raises the present value of after-tax income to \$412,621.

^{*}The analysis was restricted to assets having tangible returns; thus, life insurance reserves, security credit, and miscellaneous assets (not identified in the Federal Reserve Board Balance Sheets for the US Economy⁴⁵) were excluded because of the inherent difficulty in measuring their rates of return. For further details on the calculations, the reader is referred to the Appendix.

^{**}Returns to owner-occupied housing and consumer durables were assumed to escape taxation. The remaining tax rates were taken from Katz and Peskin. 46

^{***}The weights were derived from Federal Reserve Board⁴⁵ and Smith and Franklin.⁴⁷

[‡]In the insurance industry the difference between premium income and losses paid is known as "expense loading"; it covers the industry's overhead, costs, and profits.

^{‡‡}Application of this ratio to labor earnings results in an upward adjustment from adding non-labor income (including transfer payments and in-kind income) that more than offsets the downward adjustment from subtracting taxes. Due to data limitations, a corresponding ratio is not applied to those engaged solely in nonmarket activities such as homemakers not in the labor force—a disproportionate share of whom are females. This means that while the effects of taxes on such non-labor income are correctly ignored, adjustments for transfer payments and other in-kind income (which should be included) cannot be made for such persons.

TABLE 5—Alternative Estimates of the Value of Life, 1977 (1977 dollars)

Age Group (years)	Adjusted Willingness-to-Pay/ Human Capitalª		Standard Human Capital ^b	
	Male	Female	Male	Female
0 to 1	668,461	457,139	31,918	28,625
1 to 4	704,303	481,290	39,657	35,539
5 to 9	770,438	526,147	58,367	52,273
10 to 14	850,562	580,490	89,604	80,196
15 to 19	928,875	623,496	130,874	112,390
20 to 24	976,304	626,792	170,707	133,238
25 to 29	966,434	586,710	196,612	136,664
30 to 34	880,836	526,912	205,062	130,044
35 to 39	790,452	465,115	197,881	121,547
40 to 44	660,193	414,562	180,352	111,647
45 to 49	522,064	332,221	156,297	99,796
50 to 54	380,389	266,482	124,989	86,286
55 to 59	240,382	201,726	86,246	70,417
60 to 64	119,328	143,086	45,169	53,426
65 to 69	50,127	99,056	18,825	39,213
70 to 74	25,294	69,306	9,781	29,189
75 to 79	12,816	48,202	5,108	21,728
80 to 84	6,787	33,936	2,820	16,787
85+	2,039	9,966	943	5,705

Adjusted willingness-to-pay/human capital estimates based on the present value of both expected lifetime after-tax income and housekeeping services (where income is estimated from earnings by using the ratio of disposable income to wages and salaries equal to 1.33); an after-tax real rate of return equal to 3 per cent; an annual increase in labor productivity of 1 per cent; and a risk-aversion premium of 1.6.

^bStandard human capital estimates based on the present value of both expected lifetime earnings and housekeeping services; a real discount rate of 10 per cent; and an annual increase in labor productivity of 1 per cent. **Source:** Dolan, Hodgson, and Wun¹⁴

Finally, applying a risk aversion premium of 1.6 results in the final adjusted WTP/HK estimate of \$660,193.

As can be seen from Table 5, the result of these adjustments is a set of estimates that is consistently larger than those based on the standard HK approach. The largest differences occur in the younger age groups. For example, the adjusted WTP/HK estimates for males aged 0 to 1 is more than 20 times that of the corresponding standard HK estimate (\$668,461 versus \$31,918). Most of this particular difference is the result of using a lower discount rate in calculating the adjusted WTP/HK estimate (3 per cent versus 10 per cent). Use of the lower rate greatly increases the present value of future earnings of children—in this case, children who will not enter the labor force for at least 16 years. Thus, the adjusted WTP/HK estimates essentially eliminate one important criticism of standard HK valuesnamely that the latter place unreasonably low values on the lives of children. ‡‡‡

Similarly, the adjusted WTP/HK estimates partially overcome the problem noted earlier concerning the low values the standard HK approach produces for the elderly.

Because the adjusted WTP/HK estimates include non-labor income such as pensions and the service value of owner-occupied housing, they are somewhat larger for the aged than the corresponding standard HK estimates. For example, the adjusted WTP/HK estimate for males aged 70 to 74 is more than two and one-half times that produced by the standard HK approach (\$25,294 versus \$9,781).*

It is also interesting to compare the adjusted WTP/HK estimates with revealed-preference WTP estimates (Table 2). In doing so, it is important to note that the latter are based primarily on studies of specific population groups (generally middle-aged male workers). Thus, the comparison is relevant only for certain age-sex groups, such as males aged 40 to 44. For example, the adjusted WTP/HK estimate of \$660,193 for this group contrasts to revealed-preference WTP estimates ranging from \$260,000 to \$5,935,000.**

the standard HK estimate for males aged 40 to 44 would be only onehalf the size of the adjusted WTP/HK estimate. Furthermore, as mentioned earlier, although one can circumvent this problem to some extent by presenting estimates based on a range of discount rates, then the problem becomes one of choosing the "correct"

^{‡‡‡}Even if a lower discount rate were used to calculate the standard HK estimates, the results would be values significantly lower than the adjusted WTP/HK estimates because of the adjustments for non-labor income and the effects of taxes as well as for risk aversion. For example, if a 3 per cent discount rate were used,

^{*}As footnoted earlier in the Income section, use of age-sex specific estimates of non-labor income would increase the adjusted WTP/HK estimates even further.

^{**}With the exception of the Dardis²⁷ study, which applies to the general population, the consumption activity WTP estimates are included here since the "average" person in these studies was also a

The public policy implications of using the adjusted WTP/HK estimates can be significant. Suppose, for example, that in evaluating a hypertension screening program (with virtually no time lag between costs expended and benefits received), it is determined that unless the program is undertaken, two unidentified males aged 40 to 44, who would otherwise have lived, will die in a city having 10,000 males in this age group. A cost-benefit analysis based on standard HK estimates would value the benefits of the program at \$360,704 (2 \times \$180,352) or approximately \$36.07 (\$360,704/10,000) per person at risk. A more correct analysis done from the individual's viewpoint and based on adjusted WTP/HK estimates would value the benefits of the program at \$1,320,386 (2 × \$660,193) or approximately \$132.04(\$1,320,386/10,000) per person at risk.*** If the cost of the program were \$1.0 million, the use of standard HK values would result in the program being cut from the budget on cost-benefit grounds; whereas, use of adjusted WTP/HK values would result in the program being preserved.

Conclusions

The foregoing analysis has shown that the HK approach can be reformulated using a WTP criterion to produce estimates for valuing risks to life that embody important advantages over previously derived estimates. For example, while most cost-benefit analyses of life-saving programs have used standard HK estimates to produce benefit numbers, these have been criticized because they are not founded on sound welfare principles. The adjusted WTP/HK estimates presented here provide the necessary welfare link. In addition, they represent economic values of HK assets (lives) that are calculated on a similar basis to the values of financial assets, and thus provide policymakers with monetary values for mortality risks that are consistent, objective, and understandable.

At the same time, it is recognized that the adjusted WTP/HK estimates and the data from which they are derived can be improved upon. For example, use of age-sex specific data on non-labor income would produce improved estimates for the elderly since they receive a disproportionate share of their total income in this form and for homemakers (particularly females) not in the labor force. Furthermore, use of more detailed data on household rates of return would probably affect the estimates since there is evidence that rates of time preference vary systematically across

middle-aged male (or separate estimates for such persons were presented). For example, Blomquist's study²⁹ of seat belt use involved a sample that was 88 per cent male having an average age of 39.2 years.

***Put another way, using adjusted WTP/HK values, individuals at risk would require minimum compensation of 3.66 (\$132.04/\$36.07) times the amount they would require using standard HK values if the program were abolished.

‡For example, Friend and Blume⁵² estimated the degree of relative risk aversion corresponding to individual portfolio choices covering a wide range of assets.

demographic groups.⁵¹ Finally, an investigation of other types of risk premiums—such as those associated with various financial instruments—could provide more accurate information on risk-averse behavior.‡

Nevertheless, while a significant improvement over previous approaches, adjusted WTP/HK estimates based on more refined data cannot be regarded as a comprehensive measure of the value of life. The exclusion of intangible factors such as pain and suffering will mean that the resulting values may still underestimate the "true" value of life. For programs such as those relating to cancer, this may introduce a significant downward bias in any calculation of social benefits. In addition, as with other economic-based estimates, equity considerations also are not captured. However, a strong argument can be made that neither intangibles such as pain and suffering nor distributional aspects should be intrinsic to the method used for placing an economic value on risks to life. Instead, such factors should be left for the decision maker to weigh explicitly. Thus, despite some shortcomings, the adjusted WTP/HK estimates should be given serious consideration in evaluating programs that require monetary values of risks to life.

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ACKNOWLEDGMENTS

We would like to thank Thomas A. Hodgson for providing unpublished data and helpful comments, and Paul R. Portney, Nancy M. Gordon, and two anonymous referees for their useful suggestions. Any remaining errors are, of course, our responsibility; the opinions and conclusions expressed are not necessarily those of the Bureau of Economic Analysis or the US Department of Commerce.

APPENDIX

Definitions and Sources of Data for Computing the Discount Rate in Adjusted Willingness-to-Pay/Human Capital Calculations

Rates of Returna

Owner-Occupied Housing—Annual return on owner's equity, where the annual return includes the net value of housing services and any capital gain (loss) on the house.

^aThe rates of return are not exact matches for the weighting categories. For example, the rate of return on owner-occupied housing was used as a proxy for the rate of return on housing and land.

[Derived from: 1) BEA data on the value of the services rendered by owner-occupied residences, and the value of the net stock of owner-occupied housing; 2) University of Michigan Survey Research Center, Survey of Consumer Finances⁵³ data on median values for net equity and house value for owner-occupied non-farm housing; and 3) Data from Durkin and Elliehausen.⁵⁴]

Consumer Durables—Annual net return on the net stock of consumer durables. [Derived from: Katz and Peskin.⁴⁶]

Time and Savings Accounts—Effective interest/dividend rates paid by the FSLIC Insured Savings and Loan Association. [Derived from: Federal Home Loan Bank Board.⁵⁵]

Bonds—Yield on US Government 3–5 year issues. (Except for recent years, ownership of non-government bonds was rare; in 1970, only 2 per cent of families owned other types of bonds.)

Corporate Equity (used as the rate of return on stocks applicable to the top 1 per cent of all households)^b—Annual return on owner's equity, where the annual return includes dividend income and any capital gain (loss) on the value of the stock. [Derived from: 1) Federal Reserve Board⁴⁵ data on the market value of corporate equity owned by households, and net revaluation; and 2) BEA data on dividend payments.]

Utility Stocks (used as the rate of return on stocks applicable to the remaining 99 per cent of households)—

Average annual return on utility stock, where this is equal to dividend income. Since this is an estimate of the rate of return on the low-risk, steady income portfolios held by retired investors and other small investors, the rate of return is figured as an income annuity; the average rate of income return (excluding capital gains) on the average price of the stock over the average holding period (5 years). [Derived from: Moody's Investors Service.⁵⁸]

Non-Corporate Equity—Annual return on the owner/proprietor's equity in non-corporate business, where the annual return includes the owner/proprietor's income and any capital gain/loss on the business. [Derived from: 1) BEA data on proprietor's income; and 2) Federal Reserve Board⁴⁵ data on equity and net revaluation in non-corporate business 1

bSince there are significant differences in the stock portfolios of the top wealthholders and of those of the remaining wealthholders, two rates of return were derived for corporate equity. Wealthier individuals tend to hold large, diversified portfolios; therefore, the overall rate of return on corporate equity was used for the top I per cent of all households. The remaining stockholders tend to be small investors, such as retired persons with a preference for low risk and a steady income flow. They tend to have investment portfolios made up of one or two low-risk, steady income issues, such as utility stocks. Thus, for this group the income yield on utility stocks was used to represent the corporate rate of return. For a discussion of the distribution of investors' assets, see, Blume and Friend, se and Cohen, Zinbarg, and Zeikel. Se

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Yale's School of Organization and Management is offering its fifth Executive Program in Health Care Management, to be held June 13–18, 1982. Hospital administrators, physicians, government officials, and senior health executives will use original case materials to examine complex problems in:

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Dianne Cesaroni
Health Systems Management Group
Yale School of Organization & Management
Box 1A
New Haven, CT 06520
203/436-0626

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